finding out about FUELS

Resources Canada   Ressources Canada

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Department of
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History and Before

Heat is essential for life. Without it, the earth would be frigid, waterless and barren.

The sun, of course, is the natural source of heat on earth. Tempered by the rotation of the earth, the heat of the sun provides the temperature balance for man, animals and plants to survive. Man has feared the sun, worshipped it, and studied it. But he has never managed to control the heat or light from it. And to this day such control remains far beyond man's grasp. For in all the million or more years of man's existence, he has failed to even marginally direct the sun's rays; to partially divert them from deserts for example, or to concentrate them on ice caps.

For tens of thousands of years, the sun alone meant warmth to man until accidentally, probably through a stroke of lightning, man discovered fire. And thus civilization began.

Fire fed by wood, kept alive day-in day-out or rekindled by a natural occurrence, became man's most powerful weapon in the conquest of his environment.

Centuries later, a chance spark may have fanned into flame, and man learned to artificially produce fire. The importance of this achievement has probably never been surpassed in the history of mankind. For the ability to light a fire at will forever ended man's complete dependence on nature.

Although coal has been known for several thousand years it was not used until modern times, when it gradually replaced wood as combustion fuel.

The same may be said of petroleum, which today has mostly replaced coal.

The Chinese were the first to use petroleum oil and gas for heat and light over 2,000 years ago. The petroleum obtained from wells drilled primarily for salt was piped through bamboo from source to destination.

Until about the 15th century, Europeans prized petroleum mainly for the asphalt derived by boiling. The liquid product was used as ointment and sparingly as lamp oil. It was not until the mid-19th century and the distillation of kerosene that petroleum became popular for lighting purposes.

Modern Fuels, Modern Requirements

Every industry and most major activities of man—driving a turbine, running an engine, cooking a meal, firing a furnace, promoting a chemical reaction, etc.—require heat, the burning of fuel.

Twentieth-century technology is so sophisticated that today petroleum fuels, for example, are tailor-made for every major application. Every petroleum fuel is obtained from the crude. But every fuel is refined, blended and chemically treated to redesign, if necessary, its basic molecular structure to best meet the specific requirements of a given application. Thus premium gasoline is blended for a high-compression car engine ; 'no-lead' gasoline is designed for 1971 and later engines, etc.

Twenty-five years ago, fuel performance was judged by burning efficiency, heat output and cost. Today there are two added criteria. The fuel must be produced virtually without pollution and must burn with minimal pollution.

So important are these requirements for man's survival that, if the necessary technology is not developed soon, the combustion of coal and petroleum products may have to be replaced by other energy sources.

Fuels in Canada

Fuels have a tremendous impact on the Canadian economy as they supply all the energy requirements of most industries and serve as important trade commodities on international markets.

Petroleum is probably Canada's most important mineral. Over a million barrels flow daily from deposits that dot the Prairies, and billions of barrels more are locked in low-grade, oil-containing tar sands. Some of the world's largest and longest pipelines move the oil to markets. Canada exports only slightly more oil than it imports, because some imported crudes are lower in price since they are cheaper to extract than Canadian crudes, or they are more economically transported to eastern Canada. Every new discovery of high-grade oil, however, increases the trade balance in Canada's favor.

Natural gas is a major export commodity that plays a critical role in Canadian trade agreements with the United States.

Coal is produced in both eastern and western Canada. In general, eastern coal is best suited for heating purposes. Western, low-volatile bituminous deposits yield a metallurgical grade of coal suitable for blending with other coals for the production of high-quality coke used in blast furnaces for the reduction of iron ore. Since most of Canada's steel industry is concentrated in eastern Ontario, Canada imports coking coal from closer and, therefore, cheaper sources in the United States and exports a portion of its own production to Japan.

The Future

Known fuel deposits in Canada today will meet the demands of the coming decades. And more deposits are being discovered. But, in the long term, Canada's supply of petroleum depends on finding major new pools in the Arctic and on the Continental Shelf as well as on solving the technical and economic problems of recovering oil from the large tar-sand reserves in northern Alberta. The marketability of Canada's coal hinges partly on its transformation into metallurgical coke and partly on its ability to compete with water power and uranium as a source of electricity.

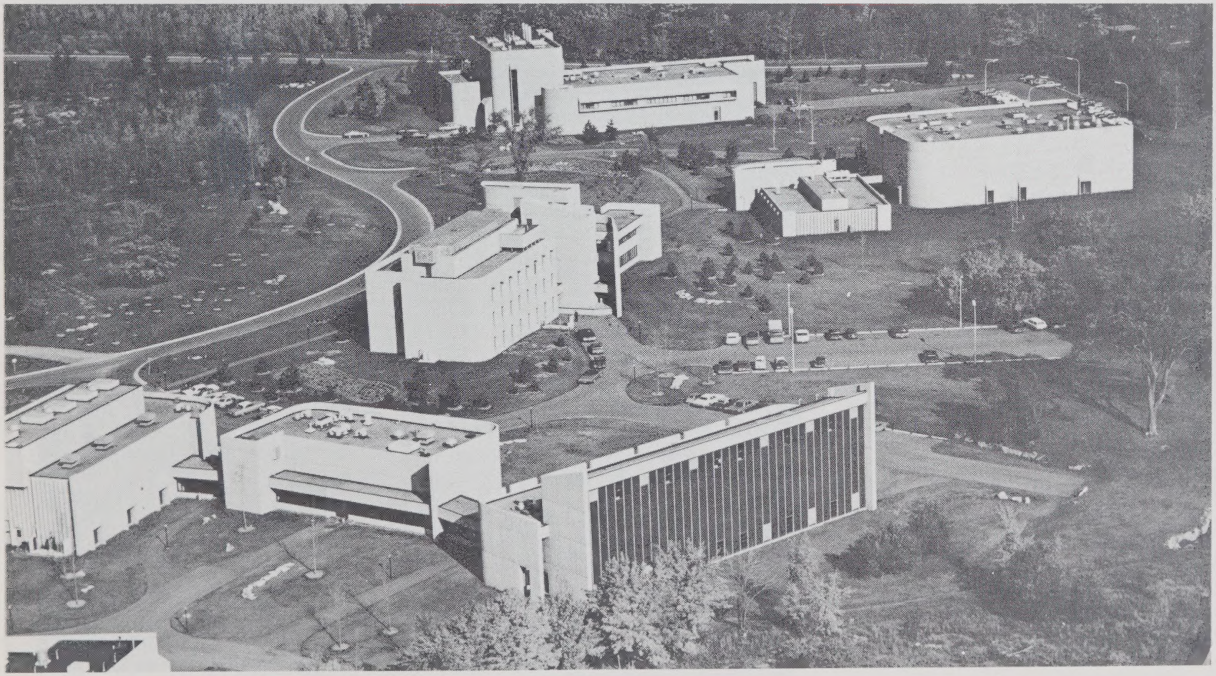
But these problems are just a part of the future. One of the important challenges facing Canada's fuel industry today is how pollution can be reduced or eliminated in the combustion of fuels.

The Mines Branch of the Department of Energy, Mines and Resources is solving the problems and meeting the challenge.

The Mines Branch

Established in 1907 to investigate coal deposits under the Mines and Geology Act, the Mines Branch today is an authority on the extraction, processing and combustion of coal and petroleum.

The Mines Branch contains a nucleus of fuel experts. Researchers in every science associated with fuel technology analyze the known to probe the unknown in attempts to solve long-term problems of the industry, problems that fall outside the scope of private enterprise either because of lack of personnel and facilities or because the subjects are not of sufficient immediate local concern. As a result the Mines Branch is deeply involved in the study of non-polluting fuel burners, the dispersion of smoke from smokestacks of coal-burning power plants, processes for the extraction of oil from tar sands, the movement of coal by pipeline, etc.



The Fuels and Mining Research Centre of the Mines Branch at Bells Corners, Ottawa. The buildings house pilot plants where research is carried out on the many facets of fuel processing, energy use, and environmental improvement.

The Mines Branch spends much time and effort in the study of fuels. But the main commitment of the Mines Branch is neither to a specific type of fuel nor to a specific segment of the fuel industry. Rather it is a commitment to the Canadian people to ensure that fuels continue to have a beneficial impact on our well-being and prosperity.

Coal Research

Coal is a carboniferous mass produced from vegetative remains by the action of heat, pressure, bacteria and other agents over very long periods of time. It is an intimate mixture of hydrocarbons, lesser amounts of sulfur, phosphorus and such mineral impurities as clays, carbonates, etc., that varies in nature and composition from deposit to deposit.

Heating coal is found in abundance in North America, Britain and other parts of the world. Coking coal, vital for the production of coke, the reducing agent in the blast-furnace smelting of iron, is currently in short supply around the globe.

To make coke for blast-furnace use, coking coals are first crushed, cleaned to remove mineral matter, then blended to obtain the best combination of coal constituents to produce a high-strength product, and, finally, carbonized or heated to red heat in the absence of air to drive off volatile matter and leave a strong but porous carbon mass. This is coke.

Coke consumed in the blast-furnace smelting process is the largest single cost item in the conversion of iron ore to pig iron in an integrated steel plant. Coke consumption per ton of pig iron is one of the most important factors affecting blast-furnace rates of production. Since consistently high-quality coke is believed to be the major factor favoring low coke-usage rates and high furnace productivities, it is imperative that only the best coking coals be used.

The composition and structure of coal determine its suitability for heating or coking applications.

For heating purposes, the moisture and sulfur contents are important. Moisture, in addition to producing no heat, retards burning rates and therefore is undesirable. Sulfur in the form of its oxides is the major pollutant resulting from the combustion of coal and must be reduced to a minimum.

"Coal-cleaning" using water cyclones. Demonstration of one method of separating mineral matter from coal so that it will meet required specifications for use in coking or combustion.

For coking, the ash, phosphorus and sulfur contents of the coal which are largely carried over to the coke, and the fusible material in the coal are vital. Ash in coke represents expensive wasted space in the blast furnace. The more ash the less payload ; as a result, a maximum of 10% ash is tolerated by the steel industry. Phosphorus and sulfur have a detrimental effect on final steel properties and also must be kept at a minimum. The amount of organic fusible matter present in the coal determines the mechanical strength of the coke produced from the coal. The fusible portion of the coal softens with heat at about 450°C during coking to bind the inert matter together and give a strong coke product upon cooling. Strength is important in coke to ensure that the coke in the furnace charge is not crushed by the load of iron ore and lime. Crushed coke tends to compact and prevent the free passage of air through the furnace, causing the furnace temperature to drop and ultimately the iron to 'freeze' to a solid.

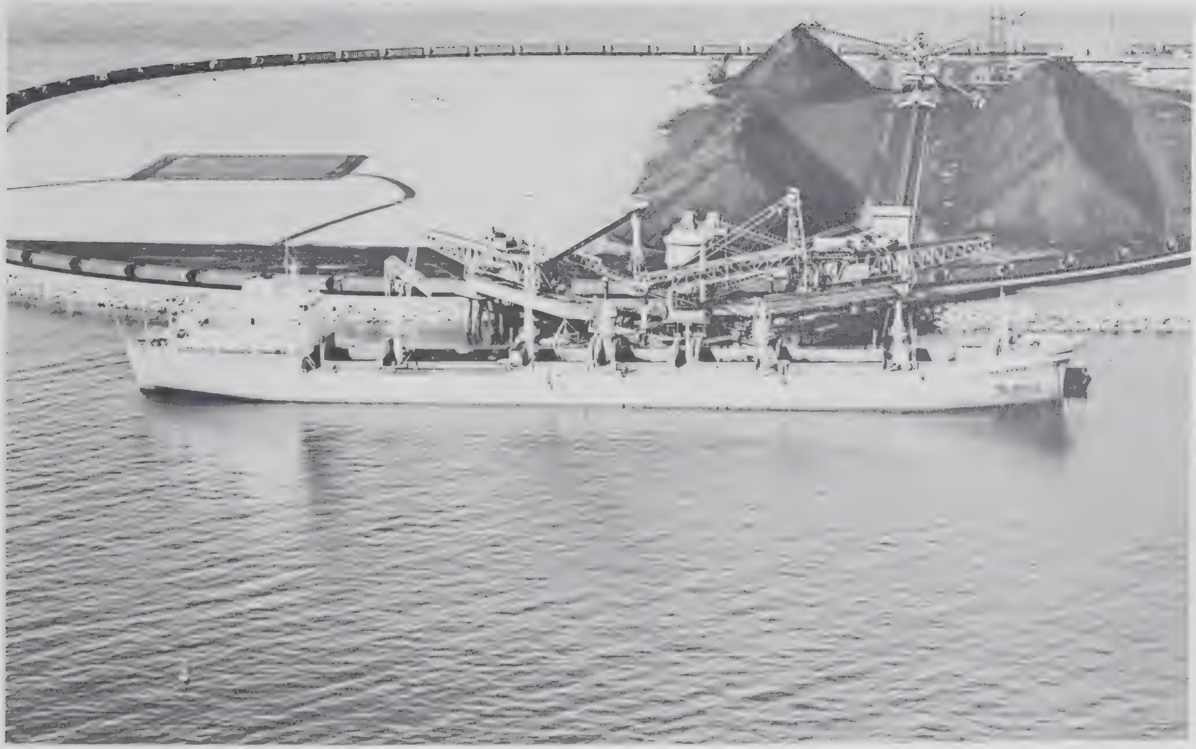
The Mines Branch, in order to help the coal industry to market its products most effectively, analyzes in depth coal samples from every known deposit in Canada. Such physical and chemical properties as moisture, ash content, volatile matter, fixed carbon and heating value are evaluated in relation to the major applications, combustion and carbonization.

But that is only the beginning of the Branch's efforts. In major studies associated with the chemical and physical behavior of coals, the Branch has found economical methods to upgrade specific properties of potential coking coals to coking quality and to improve the efficiency of utilization of coals for thermal power.

The mineral matter in coal, for example, produces the bulk of the ash in combustion. Continuing research by the Branch is successfully pin-pointing methods to economically separate the mineral impurities from specific coals by physical and chemical means. If the density difference between coal and impurities is sufficiently large, the coal can be ground, suspended in water or other liquids and the impurities separated by gravity or water cyclones. If these methods are unsuitable, separation may be possible by the preferential flotation of either coal or minerals in a selected froth. The choice of frothing agent is based on detailed knowledge of the surface properties of coals and liquid media.

The demand for high-quality coking coal is becoming more and more insistent in Canada and around the world. The Mines Branch, concerned that the Canadian coal industry be in a position to supply a consistent coking coal in the fulfillment of its long-term contracts, is focusing research on both coking techniques and the development of a form coke substitute made from coals that produce a weak coke by conventional methods. Both the preheating and the predrying of coal charges for conventional coke ovens, for example, improve the physical quality of the coke product and increase coke-oven throughput for higher production rates, thus allowing the use of a lower-quality coking coal. Form coke, molded from crushed or pelletized high-strength non-coking coals using pitch or tar as binder, is an interesting potential substitute for coke in the future. At the Mines Branch and at other coal establishments around the world, form coke is an important subject of study.

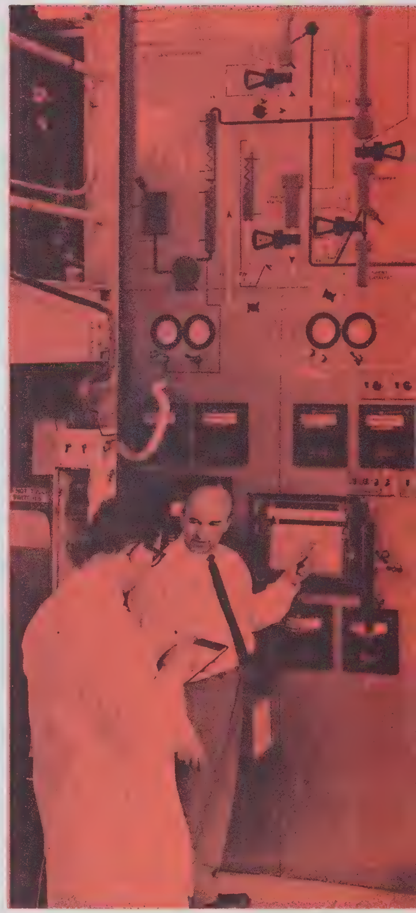
To enhance the marketability of Canada's heating coal, the Mines Branch is investigating new, more effective oil-assisted drying methods to remove the moisture from coal as well as low-cost pretreatments to eliminate traces of sulfur.

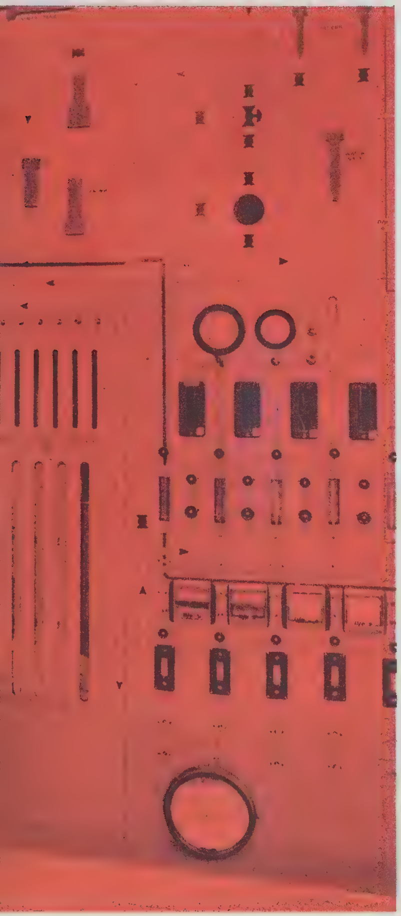


At the Roberts Bank terminal south of Vancouver, B.C., trainloads of coal from Alberta and British Columbia are loaded for shipment to Japan.

To simplify the transportation of coal, the Branch is solving the practical problems of moving coal in a water slurry by pipeline. What is the cheapest, most effective method to dewater the coal at destination ? Is it necessary to agglomerate the ground coal into specific shape for further transport by conventional means ? How can oxidation, which affects the melting properties of coal in coking, be prevented during the handling and dewatering operations ?

A consistent coking coal, a non-polluting fuel coal and cheaper transport would give Canada a competitive edge on world coal markets. The Mines Branch is working for it.





Graphic instrument panel of the Mines Branch fluid catalytic cracking pilot plant. The cracking process converts heavy oils to marketable fuels.

Petroleum Research

Petroleum breeds hundreds of products. Gasoline, heating fuels, lubricants, solvents and families of petrochemicals are produced by fractional distillation and refining of crude.

The fractionating tower that identifies an oil refinery functions as a series of stills, one on top of the other, to separate the hydrocarbons in the crude by their boiling points. Trays at different levels and different temperatures in the tower, cold at the top and hot at the bottom, serve as separation units. Preheated crude is pumped into the tower at some intermediate point. The light, more volatile components move upward from tray to tray, while the heavy ones drop down, to vaporize in fractions of gasoline, solvents, heating oils, lubricants and residual oils.

Every petroleum crude, because of its source, location and geological history, is unique in composition. The low-boiling fractions vary from crude to crude, as do the percentages of impurities. Some petroleums, for example, contain largely cyclical hydrocarbons suitable for diesel fuel; others may have large amounts of sulfur and nitrogen that require special refining steps, etc.

To give government agencies a clearer picture of the quality of Canada's natural crude oil resources, the Mines Branch, with the help of major oil-producing provinces, maintains a crude oil and natural gas survey across Canada. Samples from most producing petroleum wells across the country are analyzed physically, by inspection analyses and, if necessary, by gas chromatography to determine exactly what hydrocarbons and other materials they contain. This is part of the resource-evaluation service. The Mines Branch's major efforts are concentrated on finding methods to upgrade low-grade crudes so as to increase the yield of commercial products from Canada's petroleum resources.

The petroleum industry is competing in a very sophisticated buyer's market. The refiner interested in maximizing his profit looks for the cheapest crude oil consistent with the refining capability on hand. Industry in eastern Canada, for example, often finds it more profitable to import crudes from South America, or the Middle East,

Fuel experts analyze a sample of petroleum crude.

than to move a similar Canadian crude from the west. The reason? Individual oil pools in such countries as Iran, Kuwait and Venezuela are so much larger and closer to the surface than in Canada that extraction costs per barrel of crude are often a fraction of those of the Canadian product.

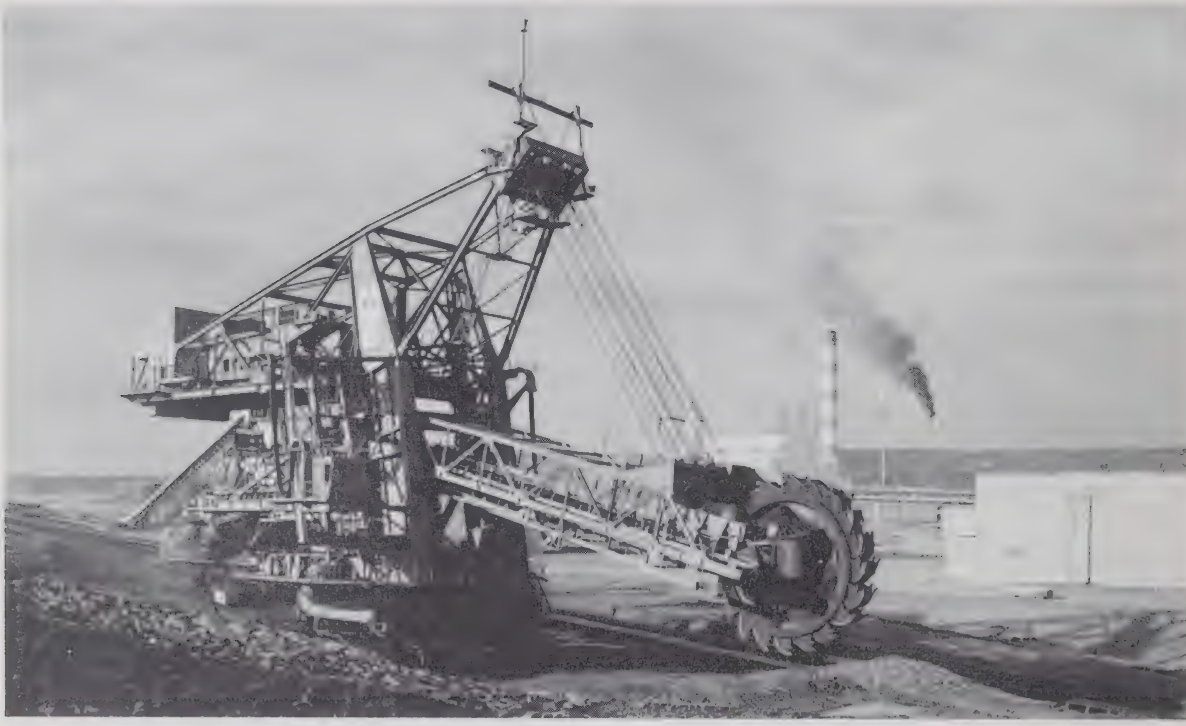
Crude oil is a blend of many pure hydrocarbons containing only hydrogen and carbon with hydrocarbons containing combined oxygen and sulfur, nitrogen or metal contaminants. Low-grade crudes contain either a large percentage of impure hydrocarbons or very high boiling hydrocarbons, rich in carbon and poor in hydrogen. They are upgraded by introducing hydrogen into their molecular structure. Heat breaks the heavy molecules down into lighter fractions that are stabilized by reaction with hydrogen to yield gasoline and fuel oils. Hydrogen also reacts with any sulfur, or nitrogen, released in the breakdown to form volatile hydrogen sulfide and ammonia.

In theory, hydrogen can be reacted directly with low-grade or residual oils at temperatures of about 450°C. Industrially, however, a catalyst is used to increase the rate of production and to improve the quality of marketable fuels. The most effective catalyst to date has a life of three months. After that the reaction vessel is shut down, and the catalyst is reactivated by burning off the carbon deposited on its surface.

Down-time is costing the Canadian petroleum industry hundreds of thousands of dollars annually. And with increasing pressure to produce low-sulfur fuels to meet air pollution restrictions, the demand for hydrogenation will become greater and greater. Down-time will become costlier.

But a solution appears not far off. The Mines Branch is obtaining encouraging results in the development of a catalyst that can be continuously added and withdrawn during hydrogenation.

In addition, the Mines Branch operates a unique continuous vacuum-distillation pilot plant. The flexibility in temperature and pressure possible with this unit allows precise separation of relatively large fractions essential, for example, in the study of the removal of impurities that affect petroleum processing.



1

1– A "bucketwheel" excavator moves 20 tons of sand in one revolution. Standing 100 feet high and weighing 1,700 tons, the excavators mines an average of 108,000 tons a day from the Athabasca tar sands. The synthetic crude extracted from the bitumen component can be refined into gasoline, kerosene and many other oil products.

2– Great Canadian Oil Sands Ltd., McMurray, Alberta was the first large-scale commercial refinery on the Athabasca tar sands of north eastern Alberta. The sands cover about 10,000 square miles and contain an estimated 626 billion barrels of oil.

2

Tar Sands

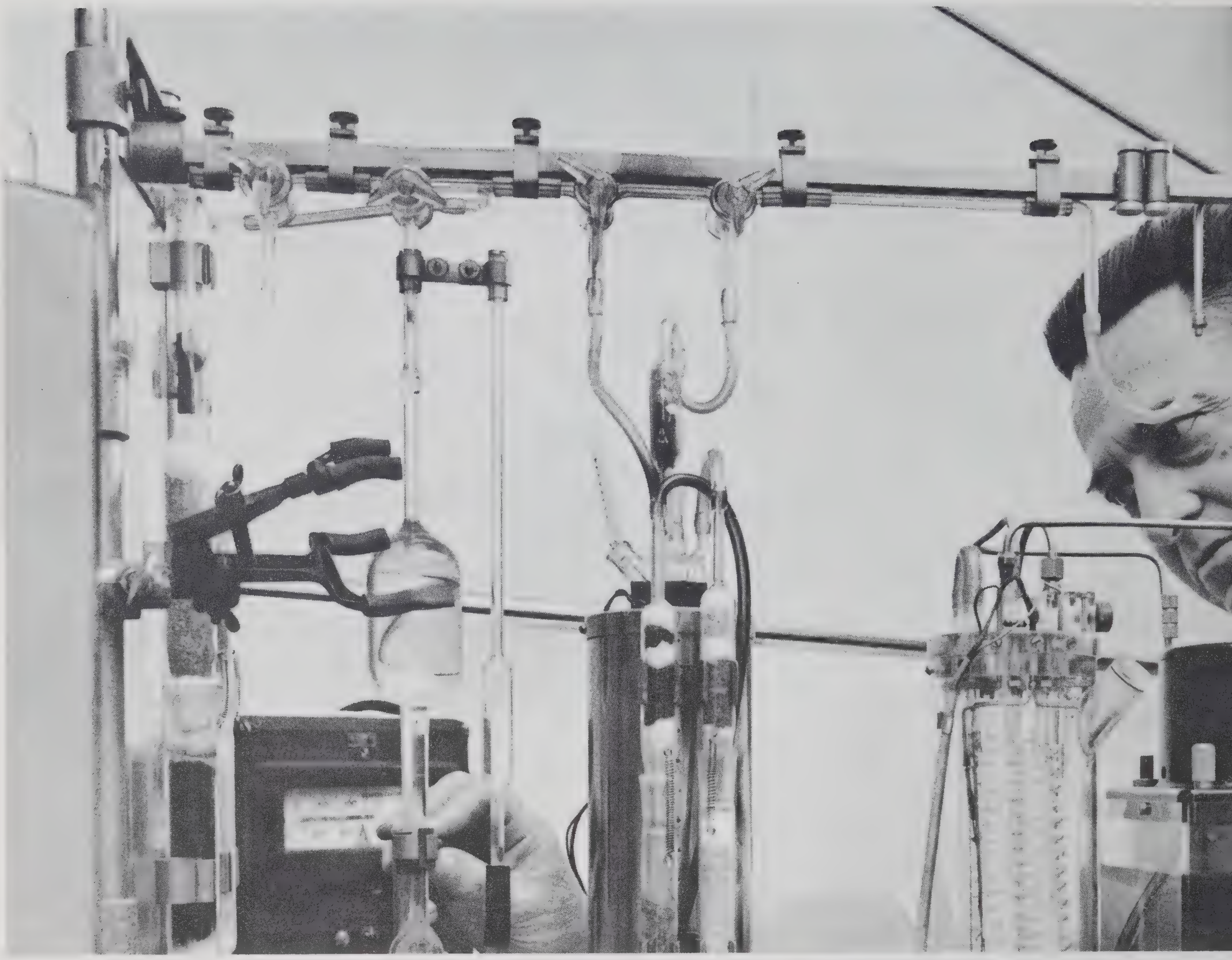
The Athabasca tar sands in northern Alberta are the largest potential Canadian petroleum source of the future. An estimated 600 billion barrels of oil are believed to be contained in the sands. Only about 10 billion barrels, however, are recoverable with present technology.

In these sands, the interstitial spaces between grains are filled with a tar-like, viscous oil similar in composition to the dregs that remain after distilling conventional crude. The oil contains clay, traces of metals and about 5% sulfur combined with the hydrocarbons in very stable complexes that can only be removed by hydrogenation.

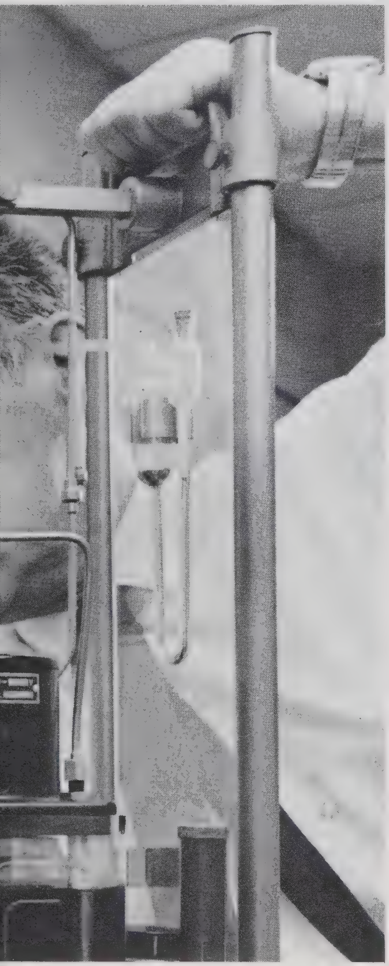
Today the oil is separated from the sand by floating it as a froth on hot water. The sand sinks and is discarded; the oil is centrifuged to remove fine mineral matter, dried and distilled. In a subsequent step, the distillate is hydrogenated to produce jet and diesel fuels. The large volume of oily sludge that remains after distillation is heated to yield gas, distillate and coke of high sulfur content.

To improve the margin of profit, the Mines Branch is studying the possibilities of a one-step hydrogenation process. Hydrogen would be introduced into the process unit together with the oil feed and a catalyst, to react directly to give a desulfurized heavy oil. The dual action of the hydrogen, removing the sulfur to form hydrogen sulfide and stabilizing the hydrocarbon fragments resulting from the thermal breakdown of the tar molecules with high molecular weight, increases substantially the yield of marketable fuels.

Success depends on maintaining a clean surface on the catalyst to prevent it from losing its effectiveness. A simple point, but vital.



One of the continuing programs at the Fuels Research Centre entails examining air samples from mines to determine the presence of explosive materials such as methane, and toxic materials such as carbon monoxide.



Safety

Coal dust, gas and petroleum fumes all form explosive mixtures with air. When is the explosive point reached in a mine shaft? An oil refinery? A fuel-blending plant? A petroleum-monitoring station? A hydrogen-gas generating unit? A fuel-storage area? Or in any enclosed atmosphere of fine dust or gas fumes?

The Mines Branch has the laboratory facilities and know-how to find the answers. As part of a unique service to reduce explosion hazards in industry, the Mines Branch analyzes potentially dangerous combustible gas samples to determine at what level of concentration in air they become explosive.

In combustible atmospheres, explosions are generally sparked by friction or static discharge from electrical equipment, moving conveyor belts, etc.

To ensure that all equipment used in combustible environments is safe, the Mines Branch, in co-operation with the Canadian Standards Association (CSA), helps to establish specifications for the manufacture of such equipment.

For example, the producer of electrical equipment must meet explosion-proof enclosure standards. His equipment must be designed to retain a spark within the housing, should one occur, or it must be intrinsically safe in that it has insufficient power to set off an explosion.

Similarly manufacturers of conveyors and plastic air-ducts must design to meet stringent fire-and-flame resistance standards.

In addition the Mines Branch tests the performance of combustibility-detector systems that roughly analyze the gas content in the air and signal when a dangerous level is attained.

Since diesel engines are used increasingly for transport in underground mines, the Mines Branch checks the exhaust emissions of such equipment to determine ventilation requirements.

But the Mines Branch is not just a safety monitor. The Branch carries out research to improve explosion-proof-enclosure design and standards, and to increase the sensitivity of gas monitoring systems.

Pollution

Air pollution is a burning issue. Fuels on combustion produce the major pollutants. To burn one pound of fuel requires fourteen pounds of gas and yields about fifteen pounds. But every phase of man's technology demands heat. And fossil fuels are the cheapest, most convenient sources of this heat. In fact, on a worldwide scale, fuels are the only practical source of heat.

Hydroelectric power is not evenly enough distributed on earth to serve as a satisfactory alternative. Nuclear power has not reached the necessary stage of development.

Although there is no simple solution to the pollution dilemma, there is a choice. Man can drastically change his way of life to reduce his need for heat and thus slow down pollution processes. Or he can attempt to reduce the polluting effect of combustion. The Mines Branch is concentrating its efforts on doing just that.

The Branch, after characterizing the pollutants in a conventional furnace-type flame, discovered that a small addition of a magnesium oxide/aluminum oxide complex to the fuel oil completely neutralizes the sulfur trioxide emitted and reduces toxic nitrogen emissions by 13 to 30 percent.

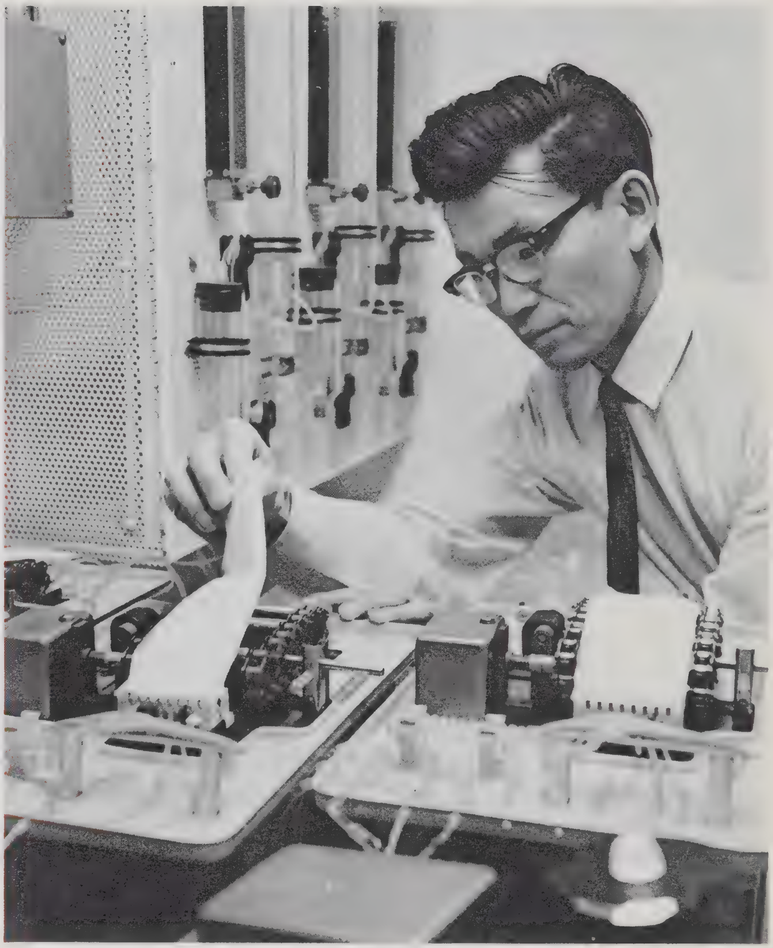
By rationalizing burner design to obtain an optimum air/temperature balance, the Branch produced an extremely efficient, virtually non-polluting flame. Now at an experimental stage, the "Blue Flame" burner design should eventually become a commodity item.

Researchers probe the flame of a fuel burner to determine the pollutants being emitted. This tunnel furnace was constructed at the Mines Branch Fuels Research Centre specifically to develop burning methods that produce minimum amounts of atmospheric pollution.

The Mines Branch has made in-depth studies of the emission plume of smokestacks to measure plume dispersion, to analyze the pollutant content, to determine the capacity of the atmosphere to accept pollutants in various weathers, and to improve smokestack design.

To promote anti-pollution standards, the Mines Branch has been evaluating the pollution emission of domestic oil burners to assist the industry to raise performance standards.

At the Mines Branch, something is being done about pollution. It may not be much on a global scale, but it is significant. Canadians may breathe easier and live longer because of it.



As combustion experiments are carried out, source pollutants are continuously monitored.

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